§41. Current Startup/Current Drive and Heating Experiments Using RF/mm-Waves on the TRIAM-1M Tokamak

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In a framework of the bi-directional collaboration organized by NIFS, new collabolation program was begun in the field of the RF heating and current drive in the TRIAM-1M tokamak. The TRIAM-1M tokamak has super-conducting magnetic coils to generate the high field up to 8T. It is an object of the collaboration to promote research activities in the subjects, specially related to the high-field tokamak experiments. In use of full characteristics of the super-conducting magnet tokamak, the steady-state operation in the lower hybrid current drive (LHCD) plasmas has been demonstrated. The Enhanced Current Drive (ECD) efficiency mode was found in the LHCD plasama, and has studied on its characteristics and relation to the transport phenomena. The start-up of the plasma current by only using radio frequency (RF) [electron cyclotron (EC) and lower hybrid (LH)] waves has been executed in the tokamak. A remote-steering antenna system for electron cyclotron heating and current drive (ECH/ECCD) has been newly developed for the experiments in the tokamak. Fundamental ECH and ECCD at the ITER frequency from the low field can be experimentally tested using the developed antenna system.

Obtained main experimental results are as the followings.

1) ECD-mode LHCD plasma experiments

Electron internal transport barrier (eITB) has been obtained in the ECD-mode LHCD plasmas. The plasma with eITB can be maintained up to 25 sec, which corresponds to more than 100 times of current diffusion time, $\tau_{L/R}$, as shown in Fig.1[1]. Self-organized slow sawtooth oscillations of plasma current, density, temperature, and so on with the period comparable to the current diffusion time have been also observed in the long duration discharges[1]. The oscillation, which has no helical structure, appears only in the high performance plasma with eITB and it seems to be induced by the variation of the transport coefficient which has relation to the current density profile estimated by the radiation from energetic electrons. In the ECD-mode LHCD plasma, ion temperature profiles became peaked. Ion internal tranport barrier has been also formed in the intermediate state of the ECD mode, as shown in Fig.2[2]. Physics of the transition associated with ITB formations and current profile effects on the sustainment of ECD/ITB modes has been investigated.

2) ECH/ECCD experiments

The ECH/ECCD experiments using the remote steering antenna have started on the TRIAM-1M tokamak for the first in the world. In the O-mode experiments, the dependence of the increased current on the steering angle in the oblique injection was observed. However, the heating effect in an improvement of the LHCD efficiency, compared to the ECCD effect, was dominant. In the X-mode experiment, there was clear difference of the plasma current in the co- and counter- steering cases, as shown in Fig.3, due to the ECCD effect on the coupling for the forward fast electrons in the energy range of 10-60keV[3]. The resonant energy range is consistent with that of the fast electrons generated by LHCD. In the off-axis ECCD experiment, the hollow profile of the hard X intensity increased by ECH/ECCD was observed. Developed antenna system has been successfully used for the ECH/ECCD expeiments in the tokamak.

The other experiments on the side-band structure in the LH wave and this disruption control by using ECH/ECCD were also carried out. More than 15 members who are specialist in the field of the RF heating and current drive experiments joined to this collaboration program. The obtained experimental results were introduced and discussed at the 19th TRIAM Workshop that was held 4-5th October. At the workshop, experimental subjects and machine time schedule in the winter experimental campaign were also discussed.

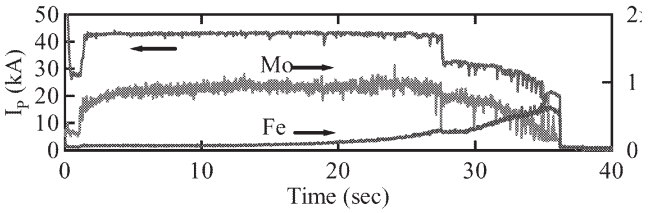

Fig. 1: Sustainment of eITB formation for 25 second in the ECD-mode LHCD plasma .

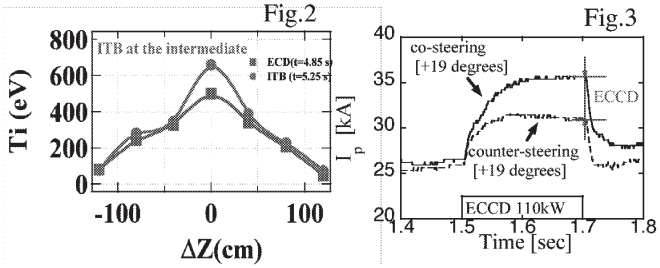

Fig. 2: Ion temperature profiles in the ECD-mode.

Fig. 3: Time evolution of plasma current in the co- and counter steering ECCD experiments.

References

[1] K. Hanada et al.,, IAEA-CN-116-EX/P4-25(2004).
[2] H. Zushi et al.,, IAEA-CN-116-OV/5-2(2004).
[3] H. Idei et al.,, IAEA-CN-116-PD/1-2(2004).